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Maeda

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(54) IMAGE CAPTURING SYSTEM, IMAGE CAPTURING METHOD, AND RECORDING MEDIUM

(75) Inventor: **Kiyohiro Maeda**, Ashigarakami-gun (JP)

(73) Assignee: **FUJIFILM Corporation**, Tokyo (JP)

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Oct. 21, 2008 (JP) 2008-271344

(51) **Int. Cl.**
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G01B 11/22 (2006.01)
H04N 5/228 (2006.01)

(52) **U.S. Cl.** **250/208.1**; 250/226; 250/339.05; 600/109

(58) **Field of Classification Search** 250/208.1, 250/226, 339.05; 600/160, 178, 180, 109
See application file for complete search history.

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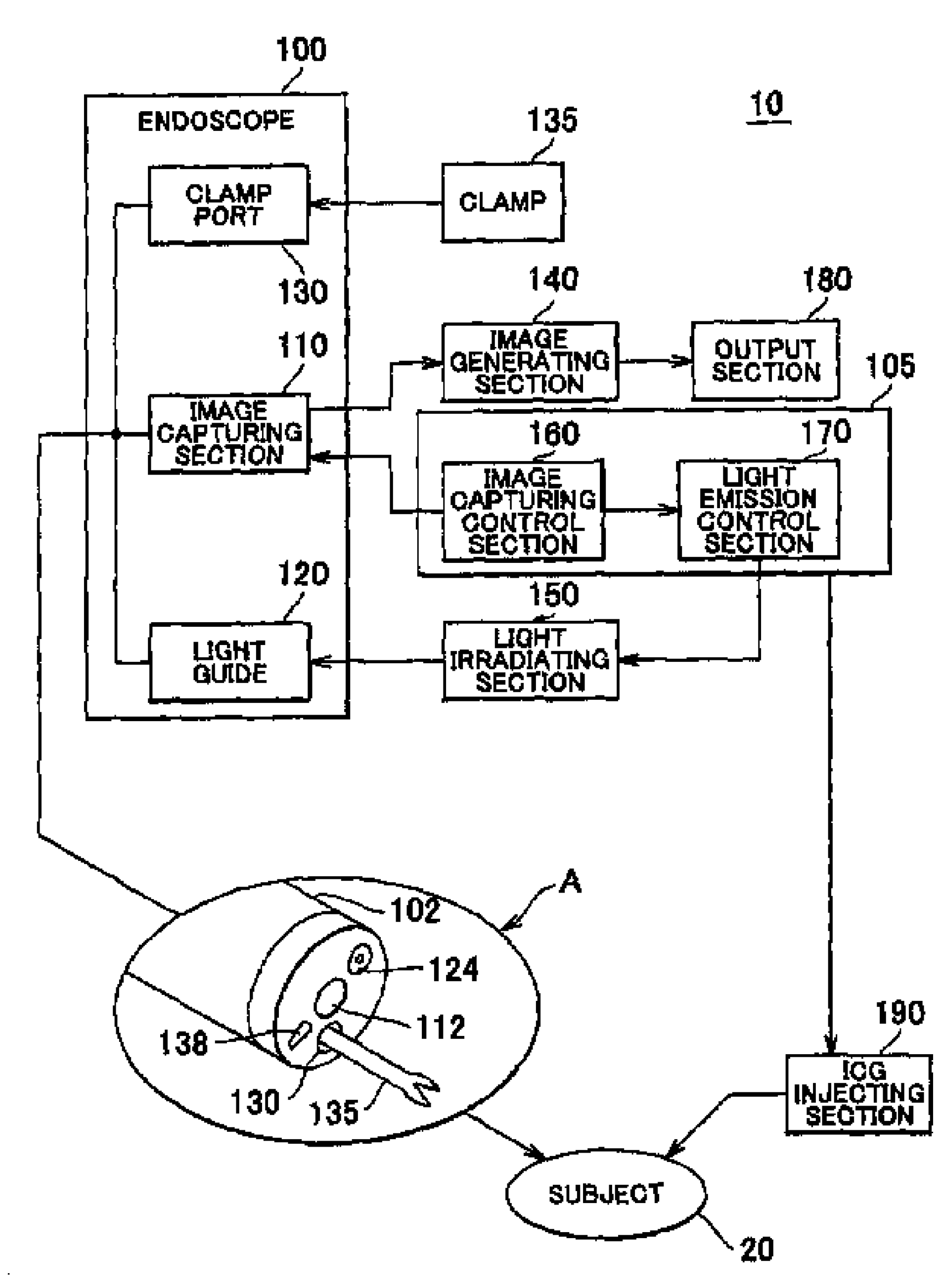
Primary Examiner—John R Lee
(74) *Attorney, Agent, or Firm*—Sughrue Mion, PLLC

(57) **ABSTRACT**

Provided is an image capturing system, including an image capturing section that includes a plurality of first light receiving elements that receive light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region, and a plurality of second light receiving elements that receive light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region; and a control section that controls a spectrum of the light received by the plurality of first light receiving elements and the plurality of second light receiving elements. The control section, at a first timing, causes the plurality of first light receiving elements to receive light in a wavelength region including the first wavelength region from a subject and causes the plurality of second light receiving elements to receive light in a wavelength region including the second wavelength region from the subject and, at a second timing, causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in a wavelength region including the specified wavelength region from the subject.

15 Claims, 10 Drawing Sheets



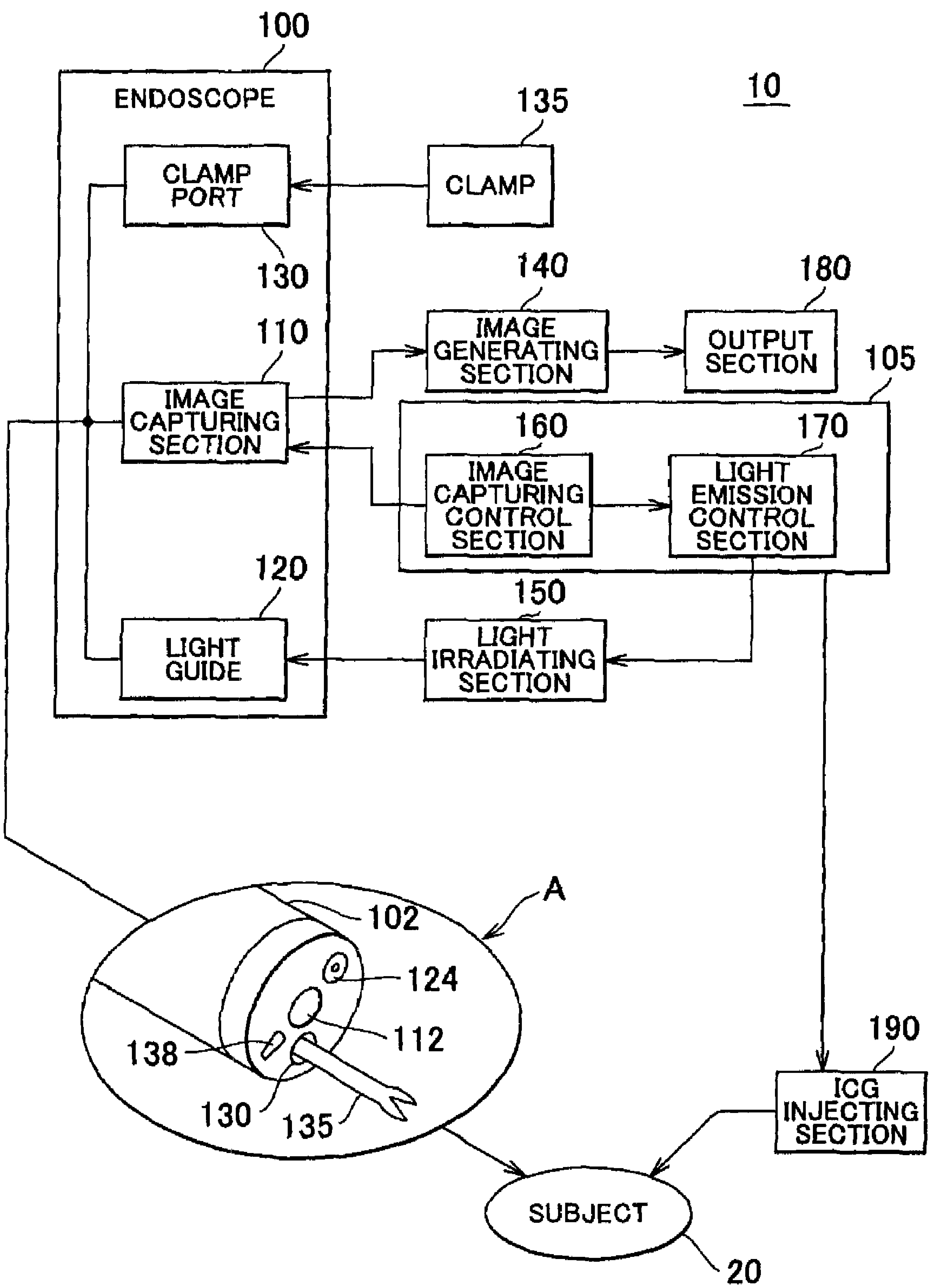

100
ENDOSCOPE
10
135
CLAMP PORT
CLAMP
130
140
180
110
IMAGE GENERATING SECTION
OUTPUT SECTION
105
IMAGE CAPTURING SECTION
160
170
IMAGE CAPTURING CONTROL SECTION
LIGHT EMISSION CONTROL SECTION
120
150
LIGHT GUIDE
LIGHT IRRADIATING SECTION
A
102
124
112
138
130
135
190
ICG INJECTING SECTION
SUBJECT
20

FIG. 1

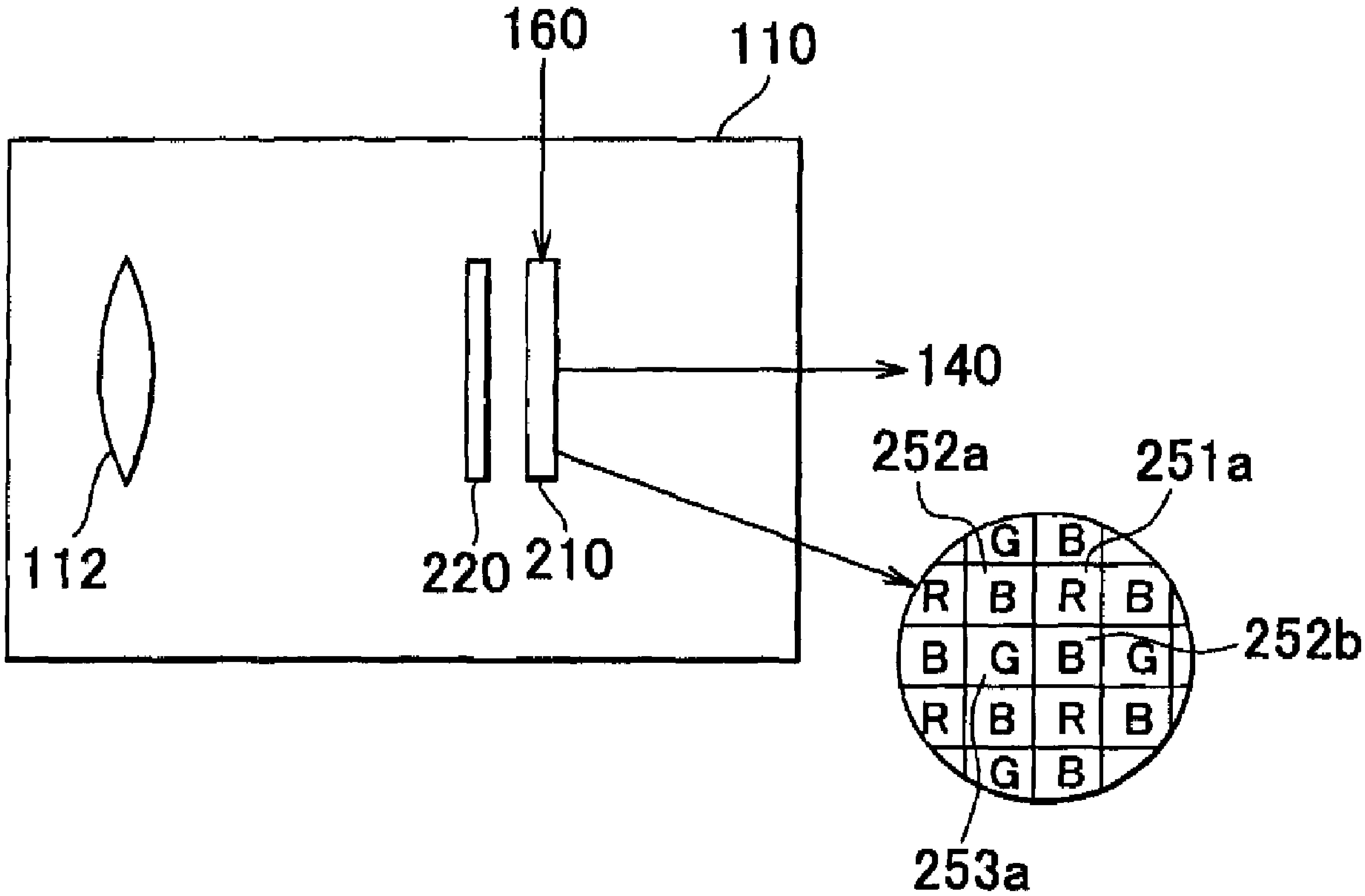
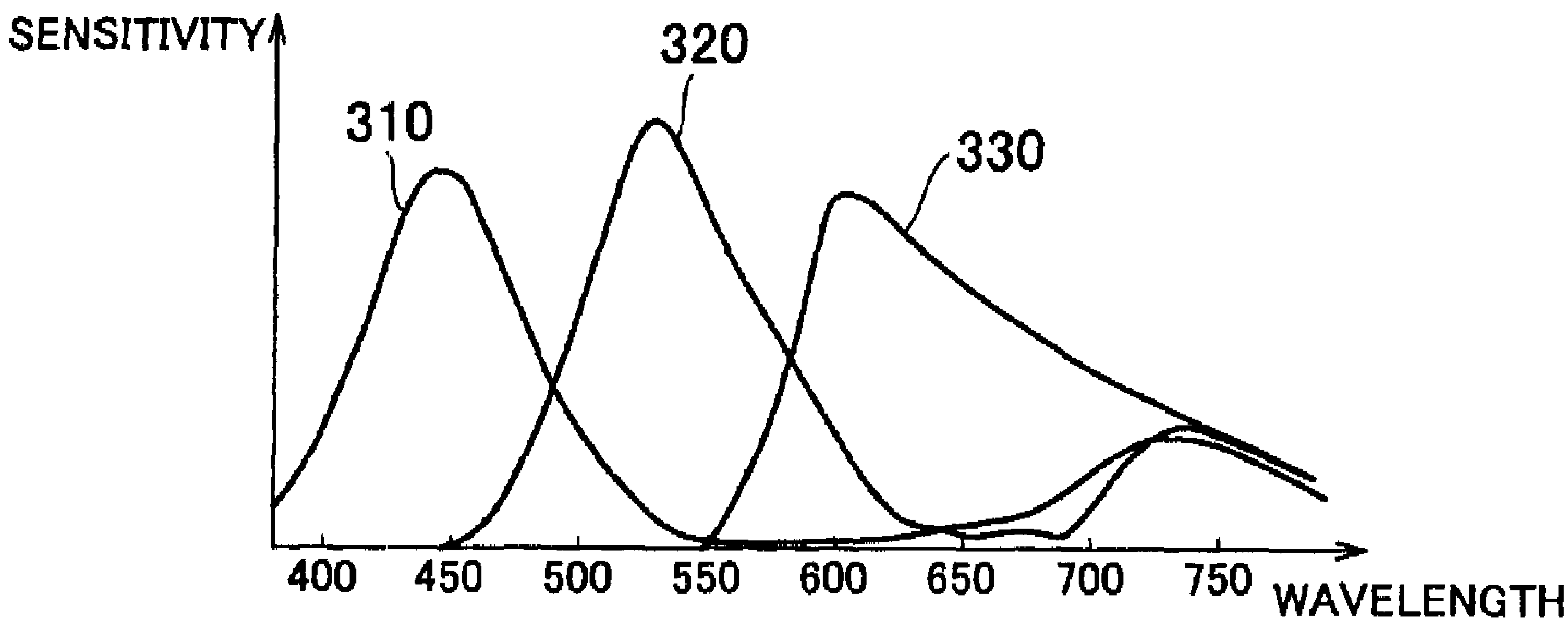

160
110
140
252a
251a
252b
253a
112
220
210
G
B
R
B
R
B
B
G
B
G
R
B
R
B
G
B

FIG. 2


SENSITIVITY
310
320
330
400
450
500
550
600
650
700
750
WAVELENGTH

F I G . 3

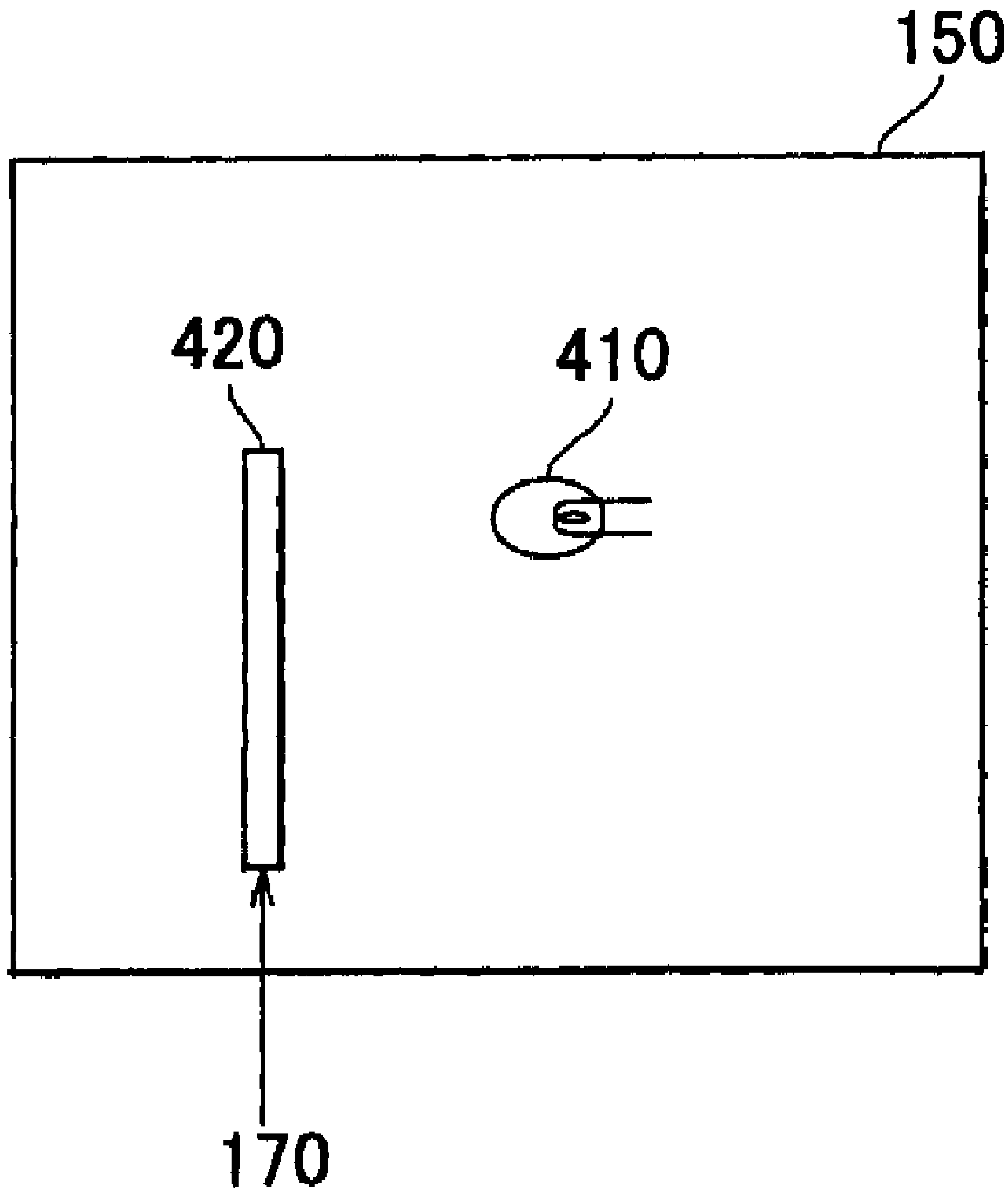


FIG. 4

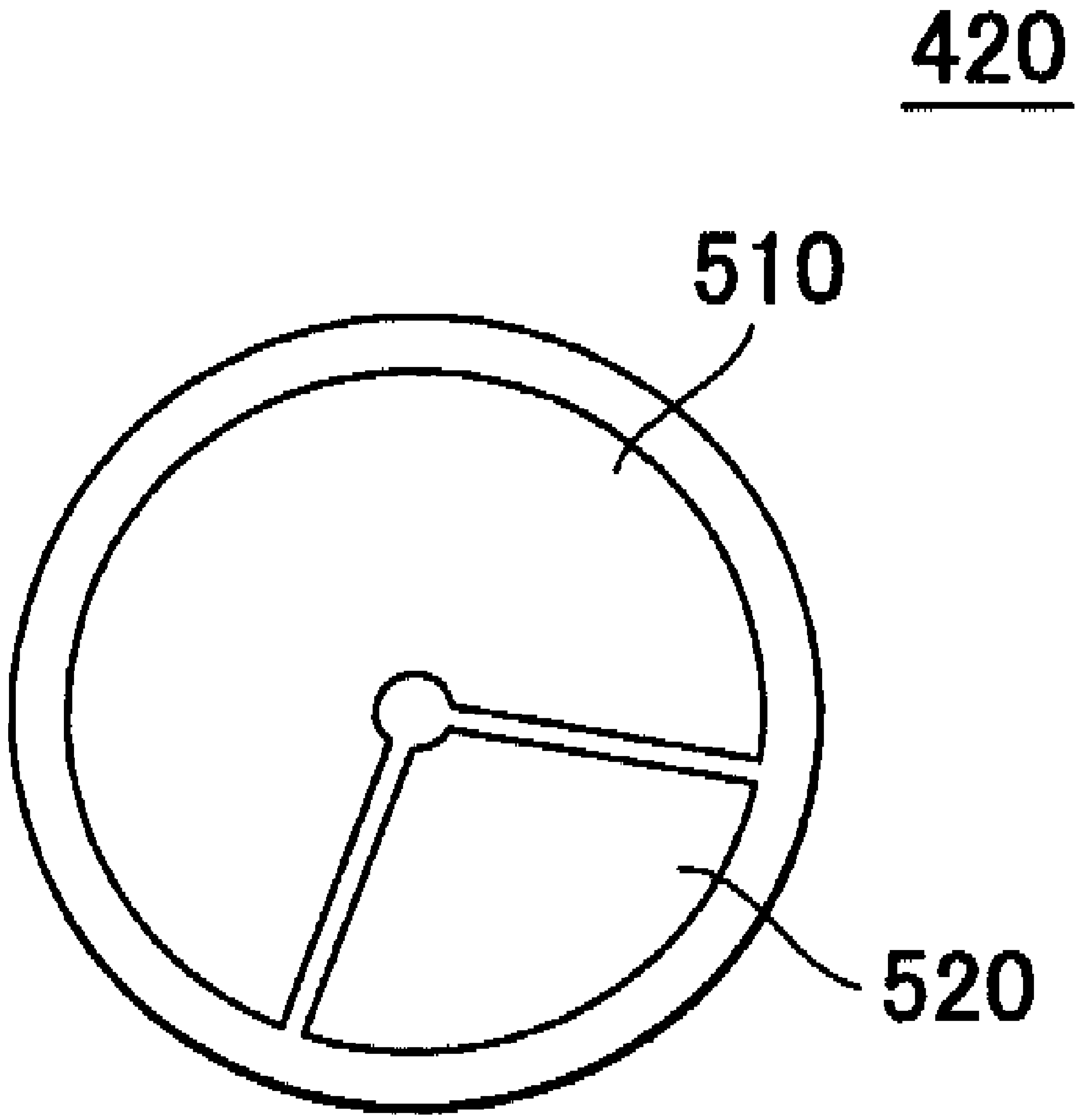


FIG. 5

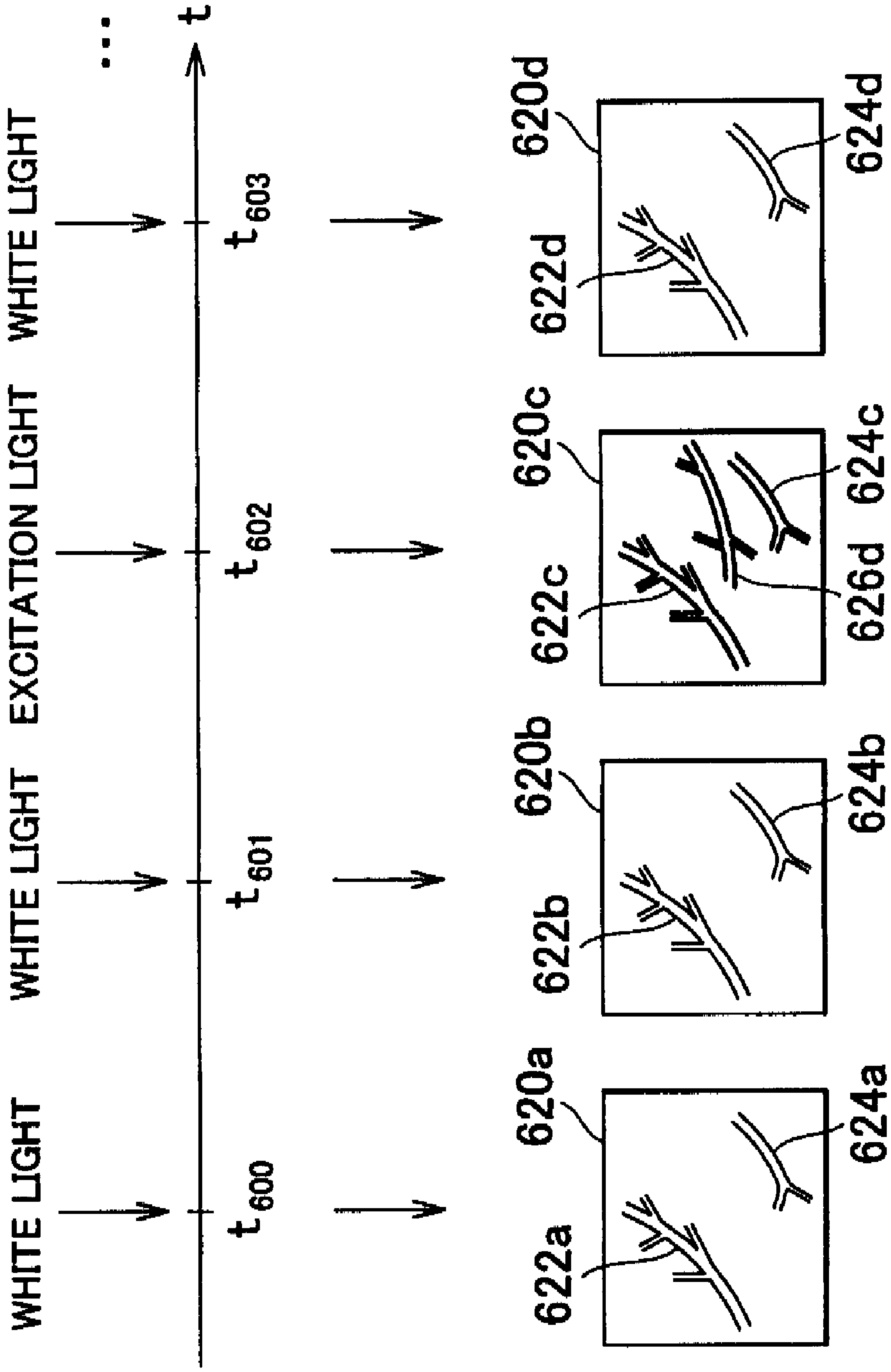

WHITE LIGHT
WHITE LIGHT
EXCITATION LIGHT
WHITE LIGHT
t
t_{600}
t_{601}
t_{602}
t_{603}
620a
622a
624a
620b
622b
624b
620c
622c
624c
626d
620d
622d
624d

FIG. 6

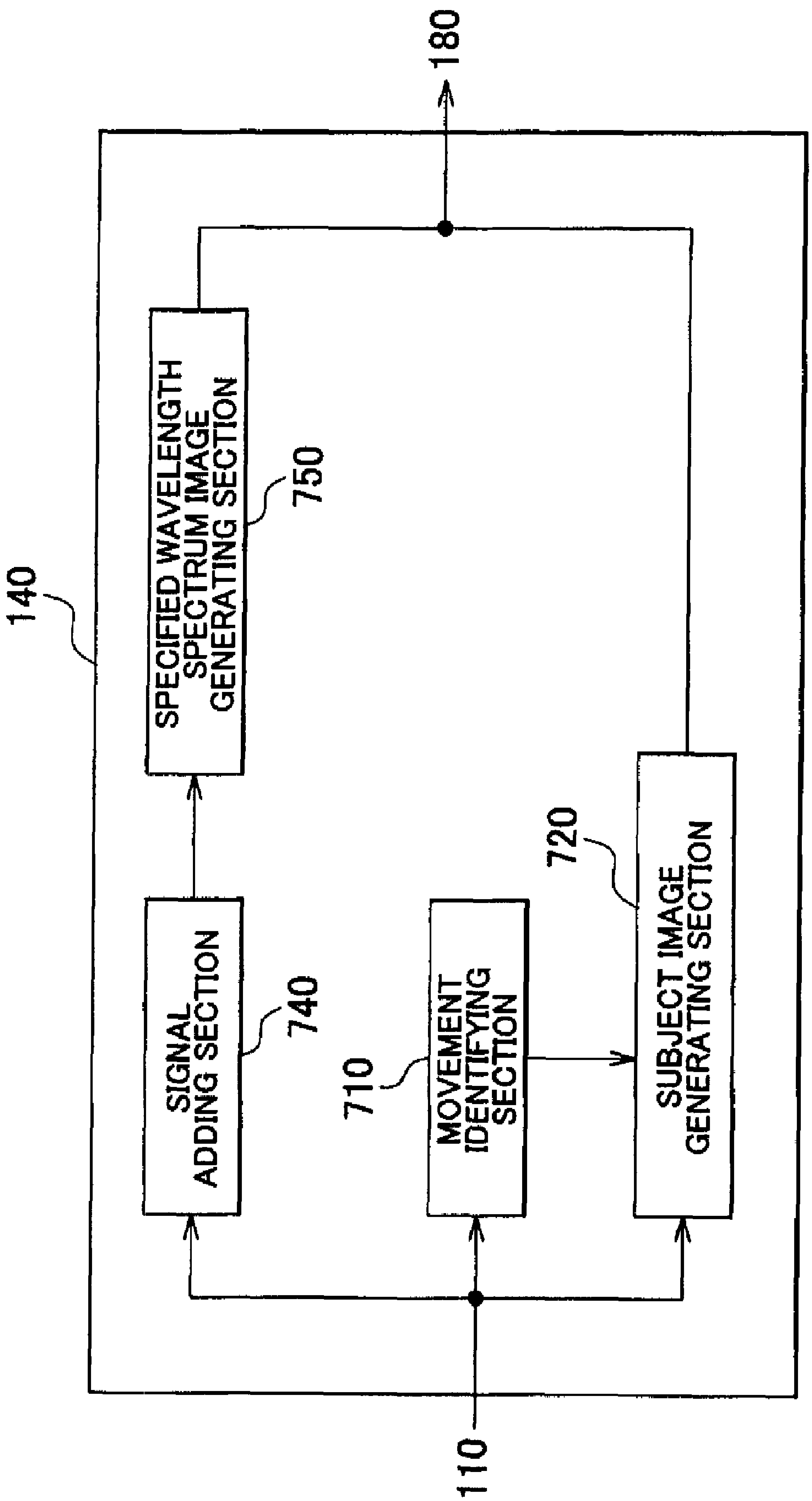
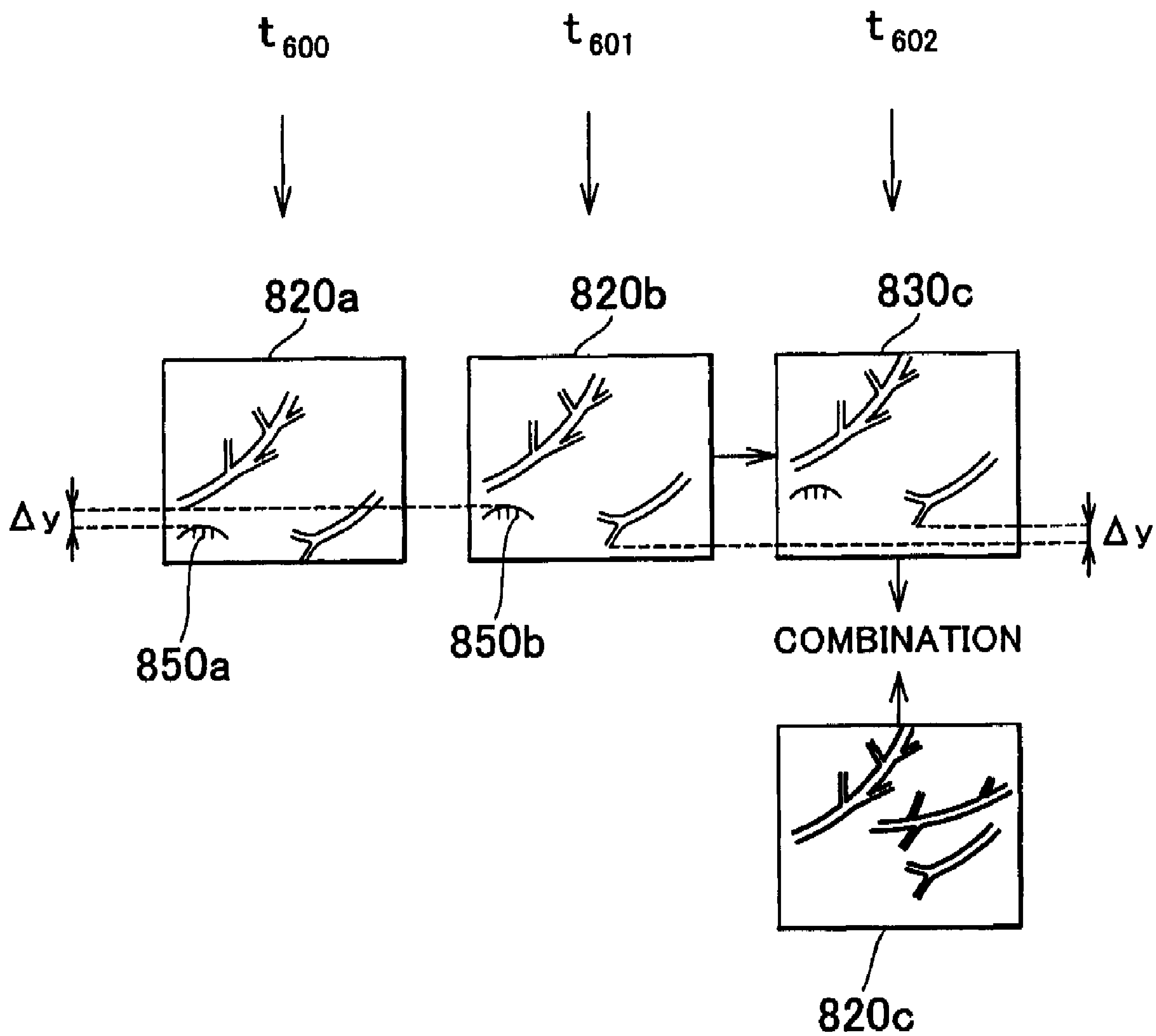

180
140
SPECIFIED WAVELENGTH SPECTRUM IMAGE GENERATING SECTION
750
SIGNAL ADDING SECTION
740
MOVEMENT IDENTIFYING SECTION
710
SUBJECT IMAGE GENERATING SECTION
720
110

FIG. 7



t_{600}
t_{601}
t_{602}
820a
820b
830c
Δy
Δy
850a
850b
COMBINATION
820c

FIG. 8

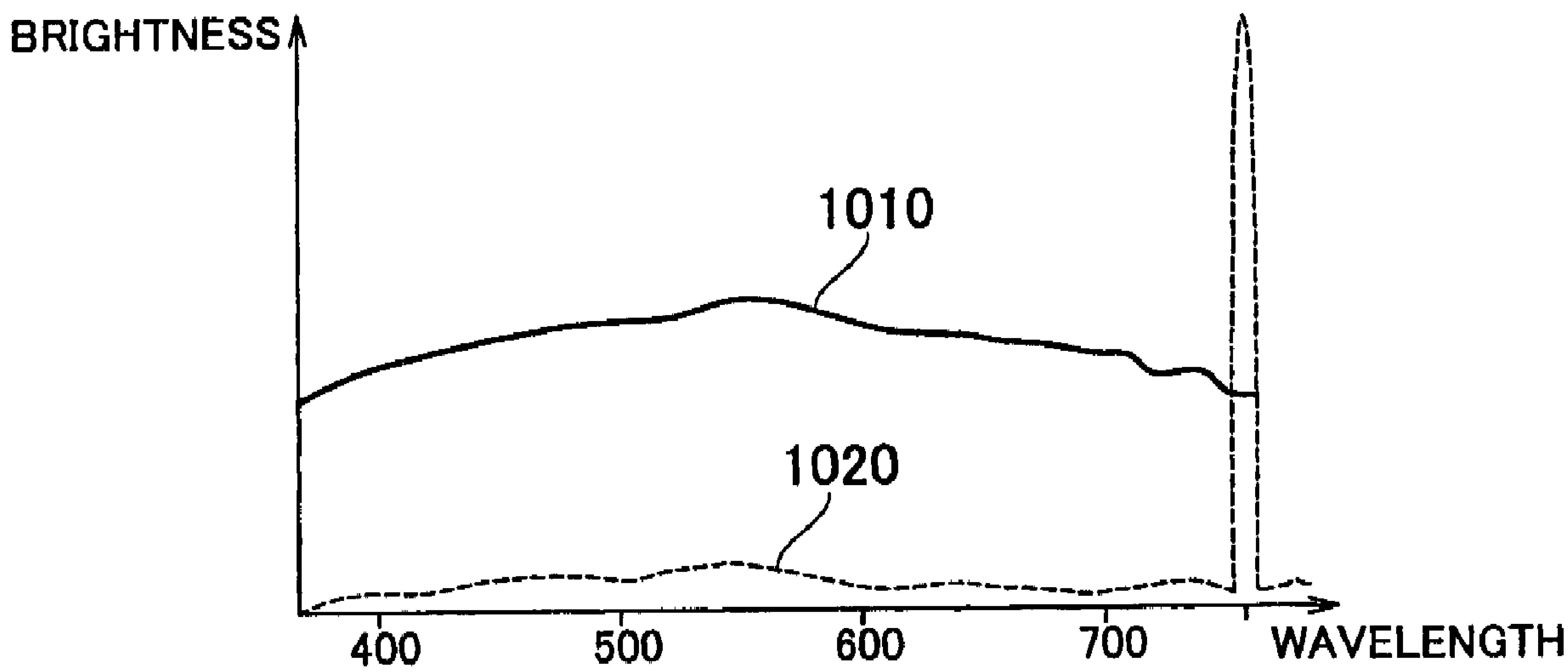


FIG. 9

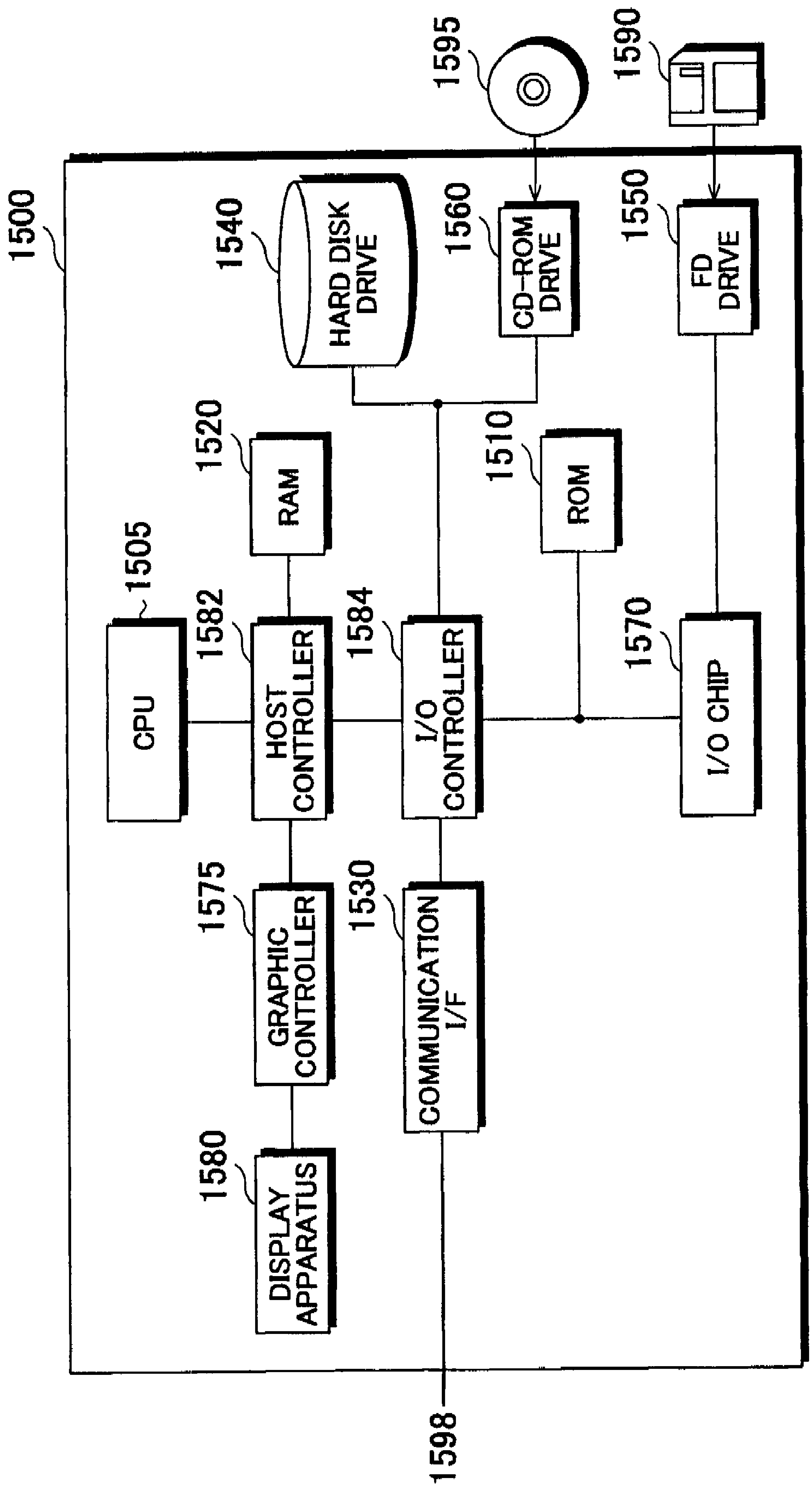

1500
1505
CPU
1582
HOST CONTROLLER
1520
RAM
1584
I/O CONTROLLER
1510
ROM
1570
I/O CHIP
1575
GRAPHIC CONTROLLER
1580
DISPLAY APPARATUS
1530
COMMUNICATION I/F
1598
1540
HARD DISK DRIVE
1560
CD-ROM DRIVE
1550
FD DRIVE
1595
1590

FIG. 10

IMAGE CAPTURING SYSTEM, IMAGE CAPTURING METHOD, AND RECORDING MEDIUM

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority from a Japanese Patent Applications No. 2007-290102 filed on Nov. 7, 2007 and No. 2008-271344 filed on Oct. 21, 2008, the contents of which are incorporated herein by reference.

BACKGROUND

1. Technical Field

The present invention relates to an image capturing system, an image capturing method, and a program. In particular, the present invention relates to an image capturing system and an image capturing method for capturing an image, and to a program used by the image capturing system.

2. Related Art

An endoscope apparatus is known that creates a fluorescent observation image using (i) an image signal of a subject captured by an image capturing means when a light source irradiates the subject with illumination light and (ii) an image signal of a subject captured by an image capturing means when a light source irradiates the subject with excitation light, as disclosed in Japanese Patent Application Publication No. 2003-79568. A known electronic endoscope includes a plurality of light receiving elements arranged in a matrix on a single semiconductor substrate, and is provided with a solid image capturing element on a tip thereof that can obtain visible light image information and fluorescent light image information, as disclosed in Japanese Patent Application Publication No. 2004-329583.

The endoscope apparatus describe above has image capturing elements that receive light in a narrow band arranged separately from image capturing elements that receive light in a broad band. The electronic endoscope described above has light receiving elements that receive visible light provided separately from light receiving elements that receive phosphorescent light. Therefore, neither the endoscope apparatus nor the electronic endoscope can obtain a visible light image and a phosphorescent light image with high resolution.

SUMMARY

Therefore, it is an object of an aspect of the innovations herein to provide an image capturing system, an image capturing method, and a recording medium, which are capable of overcoming the above drawbacks accompanying the related art. The above and other objects can be achieved by combinations described in the independent claims. The dependent claims define further advantageous and exemplary combinations of the innovations herein.

According to a first aspect related to the innovations herein, one exemplary image capturing system may include an image capturing section that includes a plurality of first light receiving elements that receive light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region, and a plurality of second light receiving elements that receive light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region; and a control section that controls a spectrum of the light received by the plurality of first light receiving elements and the plurality of second light receiving elements. The control section, at a first timing, causes the plurality of first light receiving elements to receive light in a wavelength region including the first wavelength region from a subject and causes the plurality of second light receiving elements to receive light in a wavelength region including the second wavelength region from the subject and, at a second timing, causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in a wavelength region including the specified wavelength region from the subject.

According to a second aspect related to the innovations herein, one exemplary image capturing method may include capturing an image with a plurality of first light receiving elements that receive light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region, and with a plurality of second light receiving elements that receive light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region; and controlling a spectrum of the light received by the plurality of first light receiving elements and the plurality of second light receiving elements. The controlling involves, at a first timing, causing the plurality of first light receiving elements to receive light in a wavelength region including the first wavelength region from a subject and causing the plurality of second light receiving elements to receive light in a wavelength region including the second wavelength region from the subject and, at a second timing, causing the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in a wavelength region including the specified wavelength region from the subject.

According to a third aspect related to the innovations herein, one exemplary recording medium may include a computer readable medium storing thereon a program for use by an image capturing system, the program causing the image capturing system to function as an image capturing section that captures an image using a plurality of first light receiving elements that receive light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region, and a plurality of second light receiving elements that receive light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region; and a control section that controls a spectrum of the light received by the plurality of first light receiving elements and the plurality of second light receiving elements and, at a first timing, causes the plurality of first light receiving elements to receive light in a wavelength region including the first wavelength region from a subject and causes the plurality of second light receiving elements to receive light in a wavelength region including the second wavelength region from the subject and, at a second timing, causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in a wavelength region including the specified wavelength region from the subject.

The summary clause does not necessarily describe all necessary features of the embodiments of the present invention. The present invention may also be a sub-combination of the features described above. The above and other features and advantages of the present invention will become more apparent from the following description of the embodiments taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an exemplary configuration of an image capturing system **10** according to the present embodiment, along with a subject **20**.

FIG. **2** shows an exemplary configuration of the image capturing section **110**.

FIG. **3** shows exemplary spectral sensitivity characteristics of the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253**.

FIG. **4** shows an exemplary configuration of the light irradiating section **150**.

FIG. **5** shows an exemplary configuration of the light source filter section **420**.

FIG. **6** shows the timing of the image capturing by the image capturing section **110** and exemplary images generated by the image generating section **140**.

FIG. **7** shows a block configuration of the image generating section **140**.

FIG. **8** shows the generation of a subject image in which the movement is corrected.

FIG. **9** shows an exemplary spectrum of the light irradiating the subject.

FIG. **10** shows an exemplary hardware configuration of a computer **1500** functioning as the image capturing system **10**.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

Hereinafter, some embodiments of the present invention will be described. The embodiments do not limit the invention according to the claims, and all the combinations of the features described in the embodiments are not necessarily essential to means provided by aspects of the invention.

FIG. **1** shows an exemplary configuration of an image capturing system **10** according to the present embodiment, along with a subject **20**. The image capturing system **10** is provided with an endoscope **100**, an image generating section **140**, an output section **180**, a control section **105**, a light irradiating section **150**, and an ICG injecting section **190**. In FIG. **1**, the section "A" is an enlarged view of the tip **102** of the endoscope **100**.

The ICG injecting section **190** injects indocyanine green (ICG), which is a luminescent substance, into the subject **20**, which is an example of the image capturing target. The ICG is an example of the luminescent substance in the present embodiment, but the luminescent substance may instead be a different fluorescent substance.

The ICG is excited by infra-red rays with a wavelength of 750 nm, for example, to emit broad spectrum fluorescence centered at 810 nm. If the subject **20** is a living organism, the ICG injecting section **190** injects the ICG into the blood vessels of the organism through intravenous injection. The image capturing system **10** captures images of the blood vessels in the organism from the luminescent light of the ICG. This luminescent light is an example of a specified wavelength region, and includes fluorescent light and phosphorescent light. The luminescent light, which is an example of the light from the image capturing target, includes chemical luminescence, frictional luminescence, and thermal luminescence, in addition to the luminescence from the excitation light or the like.

The ICG injecting section **190** is controlled by the control section **105**, for example, to inject the subject **20** with ICG such that the ICG density in the organism is held substantially constant. The subject **20** may be a living organism such as a person, and serves as the image capturing target for the image being processed by the image capturing system **10**. Objects such as blood vessels exist inside the subject **20**.

The endoscope **100** includes an image capturing section **110**, a light guide **120**, and a clamp port **130**. The tip **102** of the endoscope **100** includes an objective lens **112**, which is a portion of the image capturing section **110**, an irradiation aperture **124**, which is a portion of the light guide **120**, and a nozzle **138**.

A clamp **135** is inserted into the clamp port **130**, and the clamp port **130** guides the clamp **135** to the tip **102**. The tip of the clamp **135** may be any shape. Instead of the clamp, various types of instruments for treating the organism can be inserted into the clamp port **130**. The nozzle **138** ejects water or air.

The light irradiating section **150** generates the light to be radiated from the tip **102** of the endoscope **100**. The light generated by the light irradiating section **150** includes irradiation light that irradiates the subject **20** and excitation light, such as infra-red light, that is in a wavelength region that excites the luminescent substance inside the subject **20** such that the luminescent substance emits light in a specified wavelength region. The irradiation light may include a red component, a green component, and a blue component.

The light guide **120** may be formed of optical fiber. The light guide **120** guides the light emitted by the light irradiating section **150** to the tip **102** of the endoscope **100**. The light guide **120** can have the irradiation aperture **124** provided in the tip **102**. The light emitted by the light irradiating section **150** passes though an irradiation aperture **124** to irradiate the subject **20**.

The image capturing section **110** receives at least one of the light generated by the luminescent substance and the light resulting from the irradiation light being reflected by the object. The image generating section **140** generates an image by processing the received-light data acquired from the image capturing section **110**. The output section **180** outputs the image generated by the image generating section **140**.

The control section **105** includes an image capturing control section **160** and a light emission control section **170**. The image capturing control section **160** controls the image capturing performed by the image capturing section **110**. The light emission control section **170** controls the light irradiating section **150** based on the control received from the image capturing control section **160**. For example, if the image capturing section **110** performs image capturing by alternately using infra-red light, red component light, green component light, and blue component light, the light emission control section **170** controls the light irradiating the subject **20** from the light irradiating section **150** such that the timing of the irradiation with each component of the light is synchronized with the timing of the image capturing.

FIG. **2** shows an exemplary configuration of the image capturing section **110**. The image capturing section **110** includes the objective lens **112**, an image capturing device **210**, a spectral filter section **220**, and a received excitation light cut filter **230**. The image capturing device **210** includes a plurality of first light receiving elements **251** including a first light receiving element **251***a*, a plurality of second light receiving elements **252** including a second light receiving element **252***a* and a second light receiving element **252***b*, and a plurality of third light receiving elements **253** including a third light receiving element **253***a*.

The following describes the function and operation of the configurational elements in the image capturing section **110**. For the sake of simplicity, the following description refers to a single first light receiving element **251**, a single second light receiving element **252**, and a single third light receiving element **253**. Furthermore, the plurality of first light receiving elements **251**, second light receiving elements **252**, and third light receiving element **253** may be referred to simply as "the light receiving elements."

The first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** receive light from the subject via the objective lens **112**. More specifically, the first light receiving element **251** receives light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region. The second light receiving element **252** receives light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region. The third light receiving element **253** receives light in the specified wavelength region and light in a third wavelength region, which is different from the specified wavelength region.

The first wavelength region, the second wavelength region, and the third wavelength region are each different wavelength regions that do not overlap with each other. The first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** are arranged 2-dimensionally in a prescribed pattern.

The spectral filter section **220** includes a plurality of filter elements that each allow one of the light in the first wavelength region, the light in the second wavelength region, and the light in the third wavelength region to pass through, and cut light in any other wavelength region. The filter elements are arranged 2-dimensionally to correspond respectively to the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253**. Each light receiving element receives the light that passes through the corresponding filter element. In this way, the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** each receive light in a different wavelength region.

The image generating section **140** determines the pixel value for a single pixel based on at least the amount of light received by the first light receiving element **251***a*, the second light receiving element **252***a*, the second light receiving element **252***b*, and the third light receiving element **253***a*. In other words, the first light receiving element **251***a*, the second light receiving element **252***a*, the second light receiving element **252***b*, and the third light receiving element **253***a* are arranged 2-dimensionally to form a single pixel element arrangement, and a plurality of pixel elements are formed by 2-dimensionally arranging a plurality of such groups of light receiving elements forming a single pixel element arrangement. The light receiving elements are not limited to the arrangement shown in FIG. **2**, and may instead be arranged in a variety of different arrangements.

FIG. **3** shows exemplary spectral sensitivity characteristics of the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253**. The line **330**, the line **310**, and the line **320** represent the spectral sensitivity distributions of the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253**, respectively. For example, the first light receiving element **251** is sensitive to light having a wavelength around 650 nm, and the other light receiving elements are not substantially sensitive to this light. The second light receiving element **252** is sensitive to light having a wavelength around 450 nm, and the other light receiving elements are not substantially sensitive to this light. The third light receiving element **253** is sensitive to light having a wavelength around 550 nm, and the other light receiving elements are not substantially sensitive to this light.

In this way, the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** receive the red component, the green component, and the blue component of light, respectively. The first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** may be image capturing elements such as CCDs, CMOSs, or the like. The spectral sensitivity characteristics of the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253**, as represented by the line **330**, the line **310**, and the line **320**, are obtained by a combination of the spectral transmission factors of the filter elements in the spectral filter section **220** and the spectral sensitivity of the image capturing elements themselves.

FIG. **4** shows an exemplary configuration of the light irradiating section **150**. The light irradiating section **150** includes a light emitting section **410** and a light source filter section **420**. The light emitting section **410** emits light in a wavelength region that includes the wavelength region of the excitation light, the first wavelength region, the second wavelength region, and the third wavelength region. The light emitting section **410** of the present embodiment may be a xenon lamp.

FIG. **5** shows an exemplary configuration of the light source filter section **420** as seen from the direction in which the light is guided from the light emitting section **410**. The light source filter section **420** includes an irradiation light cut filter section **520** and an excitation light cut filter section **510**. The light emission control section **170** rotates the light source filter section **420** in a plane substantially perpendicular to the direction in which the light emitted by the light emitting section **410** travels, with the central axis of the light source filter section **420** serving as the center of rotation.

The excitation light cut filter section **510** cuts the light in the wavelength region of the excitation light, and allows light in the first wavelength region, light in the second wavelength region, and light in the third wavelength region to pass through. The irradiation light cut filter section **520** allows light in the wavelength region of the excitation light to pass through, but cuts light in the first wavelength region, light in the second wavelength region, and light in the third wavelength region. The light from the light emitting section **410** is guided to a position shifted from the central axis of the light source filter section **420**.

Accordingly, when the light from the light emitting section **410** is guided to the excitation light cut filter section **510**, the excitation light cut filter section **510** cuts the light in the wavelength region of the excitation light and allows the light in the first wavelength region, the light in the second wavelength region, and the light in the third wavelength region to pass through. Therefore, at this time, the subject is irradiated with the light in the first wavelength region, the light in the second wavelength region, and the light in the third wavelength region.

On the other hand, when the light from the light emitting section **410** is guided to the irradiation light cut filter section **520**, the light in the wavelength region of the excitation light is allowed pass through the irradiation light cut filter section **520**, but the light in the first wavelength region, the light in the second wavelength region, and the light in the third wavelength region are cut. Therefore, at this time, the subject is irradiated with the excitation light.

The image capturing section **110** is controlled by the image capturing control section **160** to receive the visible light reflected by the subject **20** while the visible light is being emitted, where the visible light is the light in the first wavelength region, the light in the second wavelength region, and the light in the third wavelength region. The image generating section **140** generates the visible light image based on the amount of light received by the image capturing section **110**. Furthermore, the image capturing section **110** is controlled by the image capturing control section **160** to receive the luminescent light emitted by the ICG inside the subject while the excitation light is being emitted. The image generating section **140** generates the luminescent light image based on the amount of luminescent light received by the image capturing section **110**.

The excitation light cut filter section **510** has substantially double the surface area of the irradiation light cut filter section **520**. Accordingly, if the light source filter section **420** rotates at a constant speed and the time spent receiving light for one visible light image is equal to the time spent receiving light for one luminescent light image, the visible light image can be captured at double the frame rate of the luminescent light image.

FIG. **6** shows the timing of the image capturing by the image capturing section **110** and exemplary images generated by the image generating section **140**. The image capturing control section **160** causes the image capturing section **110** to capture images at times t**600**, t**601**, t**602**, t**603**, etc. The light emission control section **170** is controlled by the image capturing control section **160** to irradiate the subject with the light emitted by the light emitting section **410** through the excitation light cut filter section **510**, at first timings that include t**600**, t**601**, and t**603**. In this way, the light emission control section **170** irradiates the subject with light in a wavelength region including the first wavelength region, the second wavelength region, and the third wavelength region at the first timings.

At the first timings, the image capturing control section **160** irradiates the subject with light in a wavelength region including the first wavelength region, the second wavelength region, and the third wavelength region. The image capturing control section **160** separates the light reflected from the object such that the first light receiving element **251** receives the light in the first wavelength region, the second light receiving element **252** receives the light in the second wavelength region, and the third light receiving element **253** receives the light in the third wavelength region. In this way, the image capturing control section **160** performs timing control that causes the first light receiving element **251** to receive the light in the first wavelength region, causes the second light receiving element **252** to receive the light in the second wavelength region, and causes the third light receiving element **253** to receive the light in the third wavelength region, at the first timings.

At second timings, which include t**602**, the image capturing control section **160** controls the timing of the light emission control section **170** to irradiate the subject with the light emitted by the light emitting section **410** through the irradiation light cut filter section **520**. In this way, the light emission control section **170** irradiates the subject with the excitation light, but not with light in a wavelength region including the first wavelength region, the second wavelength region, and the third wavelength region at the second timings.

The image capturing control section **160** causes the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** to receive light in the specified wavelength region emitted from the subject at the second timings. In this way, the image capturing control section **160** causes the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** to receive the light in the specified wavelength region from the subject at the second timings.

In this way, the control section **105** irradiates the subject with the excitation light at the second timings, and causes the first light receiving element **251** and the second light receiving element **252** to receive the light in the specified wavelength region emitted by the subject. The wavelength region of the excitation light is different from the first wavelength region, the second wavelength region, and the third wavelength region, and has a wavelength region that does not overlap with the first wavelength region, the second wavelength region, or the third wavelength region.

As described above, the control section **105** controls the wavelength region of the light received by the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253**. The image generating section **140** generates the image of the subject based on the amount of light received by the light receiving elements at the plurality of timings.

The image generating section **140** generates a visible light image **620***a*, a visible light image **620***b*, and a visible light image **620***d* based on the amount of light received by the light receiving elements at the first timings represented by t**600**, t**601**, and t**603**, respectively. The visible light image **620***a* includes a blood vessel image **622***a* and a blood vessel image **624***a*, the visible light image **620***b* includes a blood vessel image **622***b* and a blood vessel image **624***b*, and the visible light image **620***d* includes a blood vessel image **622***d* and a blood vessel image **624***d*. The visible light image **620***a*, the visible light image **620***b*, and the visible light image **620***d* include surface images showing a physical surface in addition to the blood vessel images.

The image generating section **140** generates a luminescent light image **620***c*, which includes a blood vessel image **622***c*, a blood vessel image **624***c*, and a blood vessel image **626***c*, based on the light received by the light receiving elements at the second timings, represented by t**602**. As described above, the image capturing system **10** can capture the luminescent light image **620***c* based on the luminescent light in the infra-red spectrum emitted by the subject **20** in response to the excitation light in the infra-red spectrum.

Excitation light having a wavelength longer than visible light is more difficult to absorb than visible light, and therefore such excitation light penetrates more deeply, e.g. to a depth of approximately 1 cm, to cause the luminescent light to be emitted by the subject **20**. Since the luminescent light has a longer wavelength than the excitation light, it is relatively easy for the luminescent light to reach the physical surface. Therefore, the image capturing system **10** can achieve the luminescent light image **620***c* that includes the blood vessel image **626***d* deep in the subject, which is not included in the visible light images **620***a*, **620***b*, and **620***d*.

The output section **180** may generate a composite image obtained by combining the luminescent light image **620***c* with the visible light image **620***b* or the visible light image **620***d* that are captured at timings near the timing at which the luminescent light image **620***c* is captured. The output section **180** then outputs this composite image. The output section **180** may store the luminescent light image **620***c* in association with the visible light image **620***b* or the visible light image **620***d*.

Since the image capturing section **110** does not include an infra-red cut filter in the image capturing system **10** described above, the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** can each receive the luminescent light. Accordingly, the image capturing system **10** can capture the luminescent light image **620***c* that includes a high resolution blood vessel image.

The control section **105** cuts light in the wavelength region of the excitation light and light in the wavelength region of the luminescent light out of the light from the light emitting section **410** at the timings at which the visible light images are captured. In this way, the image capturing system **10** can provide an image of the physical surface for observation, without including the blood vessel images inside the subject in the visible light image.

FIG. **7** shows a block configuration of the image generating section **140**. FIG. **6** is used to describe an exemplary process of generating a composite image by combining the visible light image **620***b* or the visible light image **620***d* with the luminescent light image **620***c*. For ease of explanation, the movement of the tip **102** of the endoscope **100**, the movement of the subject **20**, and the like do not cause a substantial change over time in the image. In this process, the visible light image and the luminescent light image **620***c* might be skewed due to movement of the tip **102** of the endoscope **100**, movement of the subject **20**, or the like.

The intensity of the luminescent light might be very small in comparison to the intensity of the visible light from the subject. In such a case, the image signal from each light receiving element might have a lower S/N ratio than the image signal resulting from the visible light.

FIG. **7** is used to describe a configuration, operation, and function of the image generating section **140** for correcting the effect the movement mentioned above on the visible light image. FIG. **7** is also used to describe a configuration, operation, and function of the image generating section **140** for decreasing the drop in the S/N ratio described above. The image generating section **140** includes a movement identifying section **710**, a subject image generating section **720**, a signal adding section **740**, and a specified wavelength region image generating section **750**.

The following describes a process performed by the image generating section **140** to decrease the drop in the S/N ratio. The signal adding section **740** performs a pixel adding process that adds together the image signals from among a first light receiving element **251**, a second light receiving element **252**, and a third light receiving element **253** that are near each other. Here, the image signal is obtained by converting a charge amount corresponding to the amount of light received by each light receiving element into the image signal. For example, this image signal may obtained by AD converting the charge amount described above. This pixel adding process can amplify the signal components. On the other hand, the amount by which the pixel adding process amplifies the random noise is small in comparison to the amount by which the signal components are amplified. Therefore, the S/N ration can be increased by the pixel adding process.

In this way, the signal adding section **740** adds together a pixel signal from at least one of the plurality of first light receiving elements **251** and a pixel signal from at least one of the plurality of second light receiving elements **252**. The specified wavelength region image generating section **750** generates an image in the specified wavelength region at the second timings based on the image signal resulting from the addition of the above image signals. In this way, image signals caused by the luminescent light from the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** can be obtained at the second timings. Therefore, the drop in resolution of the image is very small when the pixel adding process is applied to increase the S/N ratio.

Instead of the image generating section **140** performing the pixel adding process, the image capturing section **110** may perform a pixel mixing process that adds together the charge amounts generated by the light received by the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253**. In this case, the specified wavelength region image generating section **750** may generate an image resulting from the luminescent light, based on the image signal obtained by AD converting the image signal after the pixel adding process.

The following describes the function and operation of the image generating section **140** for correcting the effect of movement or the like on the visible light image. The movement identifying section **710** identifies movement of an object in an image, based on visible light images at a plurality of timings. Here, the movement of an object refers to any movement that causes a change over time in the image, such as movement of the subject **20**, movement of the tip **102** of the endoscope **100**, or a change over time of the zoom of the image capturing section **110**. The movement of the tip **102** of the endoscope **100** includes a change over time of the position of the tip **102** causing the position of the image captured by the image capturing section **110** to change over time, and a change over time of the orientation of the tip **102** that causes the direction in which the image capturing section **110** captures the image to change over time.

The movement identifying section **710** identifies the movement of an object based on the visible light image at the times t**600** and t**601**. For example, the movement identifying section **710** identifies the movement of the object by matching the objects extracted from a plurality of visible light images.

The subject image generating section **720** corrects the image signal at the time t**601** based on the identified movement, and generates the image signal that is expected for the time t**602**. In this way, the subject image generating section **720** can generate the subject image at time t**602**.

FIG. **8** shows the generation of a subject image in which the movement is corrected. The visible light image **820***a* is the image generated by the image signals from the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** at the time t**600**. The visible light image **820***b* is the image generated by the image signals from the first light receiving element **251**, the second light receiving element **252**, and the third light receiving element **253** at the time t**601**.

Here, the movement identifying section **710** identifies the movement based on the content of the visible light image **820***a* and the visible light image **820***b*. More specifically, the movement identifying section **710** extracts objects from the visible light image **820***a* and the visible light image **820***b* that show the same subject. In the present embodiment, the movement identifying section **710** extracts the objects **850***a* and **850***b* from the visible light image **820***a* and the visible light image **820***b*, respectively.

The movement identifying section **710** calculates the difference in position between the object **850***a* and the object **850***b*. In FIG. **8**, for ease of explanation, the position difference exists in the y-direction of the image so that the movement identifying section **710** calculates a positional difference Δy indicating the positional difference between the object **850***a* and the object **850***b*. The subject image generating section **720** generates the visible light image **830***c*, which is an example of the subject image in the present invention, by shifting the image **821***b* in the y-direction by an amount corresponding to the calculated positional difference Δy.

The above describes an example in which the movement is identified using the visible light image **820**, but the movement can be identified in the same manner using the images of any other component. The decision concerning which image's wavelength the movement identifying section **710** uses to identify the movement can be decided based on the contrast of the captured image. For example, the movement identifying section **710** can prioritize the use of the image having the highest contrast for identifying the movement. If an object with a minute structure is used as the object for identifying the movement, i.e. it is clear that the object has a very fine surface structure, using the image of the B signal might enable more accurate movement identification. If an object with an uneven structure is used for identifying the movement, i.e. it is clear that the object has a bumpy surface structure, using the image of the G signal might enable more accurate movement identification.

The subject image generating section **720** may change the movement correction amount for each image region in the visible light image. For example, if the image capturing direction of the image capturing section **110** is perpendicular to the surface of the subject and the tip **102** of the endoscope **100** moves horizontally in relation to the surface of the subject, the movement amount of the object is the same in every image region. On the other hand, if the image capturing direction of the image capturing section **110** is not perpendicular to the surface of the subject, for example, the movement amount in image regions captured at positions further from the tip **102** might be smaller than the movement amount in image regions captured at positions closer to the tip **102**.

In order to calculate the movement correction amount for each image region in the visible light image, the subject image generating section **720** can calculate the movement correction amount based on the position of an image region and a positional relationship between the surface of the subject and the image capturing section **110**, if this positional relationship is known in advance or can be estimated. The subject image generating section **720** may calculate the movement correction amount for the visible light image based on a control value that manipulates the endoscope **100** to cause a change over time in the image. The control value may be a value that controls the position or orientation of the tip **102**, a value that controls the zoom of the image capturing section **110**, or the like.

As another example, the movement identifying section **710** may calculate the movement of the object in each image region. The subject image generating section **720** may calculate the movement correction amount for each image region in the image based on the movement of an object in each image region.

When identifying the movement in each image region, the movement identifying section **710** may determine which wavelength image is used to identify the movement in each image region. For example, the movement identifying section **710** calculates the contrast of each image region in each image. The movement identifying section **710** may then give priority to selecting the image of the wavelength for which the highest contrast was calculated and uses this image for the corresponding image region. The movement identifying section **710** uses the plurality of selected images to identify the movement of the objects.

The above example uses the visible light image **820***a* and the visible light image **820***b* to identify the movement, but the movement identifying section **710** may instead identify the movement using the visible light image **820***b* and the visible light image obtained at the time t**603**. In this way, the movement identifying section **710** may identify the movement based on the images obtained at a plurality of timings before and after the time t**601**, which is the timing at which the visible light image in which the movement is corrected is generated. If it is acceptable for the display of the visible light image to be somewhat delayed, the movement identifying section **710** can more accurately identify the movement by also using images at later timings. The movement identifying section **710** may identify the movement using visible light images, or images of each color component, captured at three or more timings.

As described in relation to FIGS. **7** and **8**, the movement identifying section **710** identifies the movement of an object between images at a plurality of timings based on a plurality of images caused by light received by the first light receiving element **251** or the second light receiving element **252** at a plurality of first timings. The subject image generating section **720** generates the subject image at the second timing resulting from light in a wavelength region including the first wavelength region and light in a wavelength region including the second wavelength region, based on light in the first wavelength region received by the first light receiving element **251** at the first timing, light in the second wavelength region received by the second light receiving element **252** at the first timing, and the identified movement.

FIG. **9** shows an exemplary spectrum of the light irradiating the subject. The line **1010** represents the spectrum of substantially white light, which irradiates the subject at the first timings t**600**, t**601**, and t**603**, as described in FIG. **6**.

The line **1020** represents the spectrum of the light irradiating the subject at the second timing t**601** described in FIG. **6**. As shown by this spectrum, the irradiation light may have a substantial spectral intensity in the wavelength region of visible light at the second timing. The spectrum of the irradiation light at the first timings and the spectrum of the irradiation light at the second timing are different in the specified wavelength region, which is the wavelength region of the excitation light. As shown in FIG. **10**, the light irradiating section **150** may radiate light that in which a ratio of the spectral intensity of the specified wavelength region to the spectral intensity of the first wavelength region changes such that this ratio is larger at the second timing than at the first timings. More specifically, the light irradiating section **150** radiates light at the first timings in which the spectral intensity of the first wavelength region is greater than the spectral intensity of the specified wavelength region, and radiates light at the second timing in which the spectral intensity of the specified wavelength region is greater than the spectral intensity of the first wavelength region. The above description showed a ratio between the spectral intensity in the first wavelength region and the spectral intensity in the specified wavelength region, but the spectral intensity in the first wavelength region may be replaces with the spectral intensity in the second wavelength region or in the third wavelength region.

FIGS. **4** and **5** describe an embodiment in which the irradiation light cut filter section **520** cuts the light in the first wavelength region, but the irradiation light cut filter section **520** need not completely cut the light in the wavelength region of visible light. Even if the light having a spectral intensity in the wavelength region of visible light is radiated at the second timing, an image of the specified wavelength region can be obtained at the second timing as long as the irradiation light has a spectral intensity in the specified wavelength region sufficient for achieving a clear luminescence image.

As described in relation to FIG. **9**, the control section **105** controls the spectrum of the light received by the first light receiving element **251** and the second light receiving element **252**. More specifically, at the first timings, the control section **105** causes the first light receiving element **251** to receive light in a wavelength region that includes the first wavelength region reflected by the subject, and causes the second light receiving element **252** to receive the light in a wavelength region including the second wavelength region from the subject. At the second timing, the control section **105** causes the first light receiving element **251** and the second light receiving element **252** to receive light in a wavelength region that includes the specified wavelength region from the subject. Here, the light in the wavelength region that includes the first wavelength region from the subject may be light that includes mainly light in the first wavelength region. The light in the wavelength region that includes the second wavelength region from the subject may be light that includes mainly light in the second wavelength region. The light in the wavelength region that includes the specified wavelength region may be light that includes mainly light in the specified wavelength region.

FIGS. **4** and **5** are used to describe an operation of the light irradiating section **150** that involves controlling the spectrum of the irradiation light from the light emitting section **410** over time by rotating the light source filter section **420**. As another example, the light irradiating section **150** need not include the light source filter section **420**. More specifically, the light emitting section **410** may include a plurality of light emitting elements that each emit light in a different spectrum. In this case, the control section **105** may control the light irradiating the subject at the first timings and the second timing by controlling the spectral intensity of each light emitting element.

For example, the light emitting section **410** may include a light emitting element that emits light in the red wavelength region, a light emitting element that emits light in the blue wavelength region, a light emitting element that emits light in the green wavelength region, and a light emitting element that emits light in the excitation light wavelength region. Semiconductor elements such as LEDs may be used as the light emitting elements that emit visible light. A semiconductor element such as a semiconductor laser may be used as the light emitting element that emits the excitation light. The light emitting elements may instead be fluorescent bodies that emit luminescent light such as fluorescence when excited.

The control section **105** can control the spectrum of the light irradiating the subject by controlling the emission intensity of each light emitting element at each timing. Here, "controlling the emission intensity of each light emitting element" involves changing the combination of light emitting elements that emit light at each timing. Each light emitting element may include a light emitting body and a filter that allows selected light in a specified wavelength region to pass through. Any type of light emitting elements can be used as the plurality of light emitting elements that each emit light in a different spectrum, as long as the light that has been emitted from the light emitting body and has passed through the filter results in light in different spectrums.

The light emitting elements may be provided on the tip **102** of the endoscope **100**. The light emitting elements may emit light in response to electric excitation, or may emit light in response to optical excitation. If the light irradiating section **150** includes light emitting elements emit light in response to optical excitation, the light irradiating section **150** also includes an exciting section that emits light for exciting the light emitting elements. These light emitting elements may emit light in different spectrums according to the wavelength of the light used for excitation. In this case, the control section **105** can control the spectrum of the irradiation light by controlling the wavelength of the light used for excitation emitted by the light emitting section at each timing. As another example, the spectrum of the light emitted by each light emitting element in response to the light used for excitation may be different for each light emitting element. As yet another example, light used for excitation that has passed through the light emitting elements may serve as the irradiation light for irradiating the subject.

By applying the image capturing system **10** described above to an actual system, when a doctor or the like performs surgery while watching the video displayed by the output section **180**, the doctor can observe internal blood vessels that cannot be seen at the surface. Furthermore, the image capturing system **10** described above enables the doctor to perform surgery while seeing the internal blood vessels of the subject.

FIG. **10** shows an exemplary hardware configuration of a computer **1500** functioning as the image capturing system **10**. The image capturing system **10** according to the present embodiment is provided with a CPU peripheral section that includes a CPU **1505**, a RAM **1520**, a graphic controller **1575**, and a display apparatus **1580** connected to each other by a host controller **1582**; an input/output section that includes a communication interface **1530**, a hard disk drive **1540**, and a CD-ROM drive **1560**, all of which are connected to the host controller **1582** by an input/output controller **1584**; and a legacy input/output section that includes a ROM **1510**, a flexible disk drive **1550**, and an input/output chip **1570**, all of which are connected to the input/output controller **1584**.

The host controller **1582** is connected to the RAM **1520** and is also connected to the CPU **1505** and graphic controller **1575** accessing the RAM **1520** at a high transfer rate. The CPU **1505** operates to control each section based on programs stored in the ROM **1510** and the RAM **1520**. The graphic controller **1575** acquires image data generated by the CPU **1505** or the like on a frame buffer disposed inside the RAM **1520** and displays the image data in the display apparatus **1580**. In addition, the graphic controller **1575** may internally include the frame buffer storing the image data generated by the CPU **1505** or the like.

The input/output controller **1584** connects the hard disk drive **1540**, the communication interface **1530** serving as a relatively high speed input/output apparatus, and the CD-ROM drive **1560** to the host controller **1582**. The communication interface **1530** communicates with other apparatuses via the network. The hard disk drive **1540** stores the programs used by the CPU **1505** in the image capturing system **10**. The CD-ROM drive **1560** reads the programs and data from a CD-ROM **1595** and provides the read information to the hard disk drive **1540** via the RAM **1520**.

Furthermore, the input/output controller **1584** is connected to the ROM **1510**, and is also connected to the flexible disk drive **1550** and the input/output chip **1570** serving as a relatively high speed input/output apparatus. The ROM **1510** stores a boot program performed when the image capturing system **10** starts up, a program relying on the hardware of the image capturing system **10**, and the like. The flexible disk drive **1550** reads programs or data from a flexible disk **1590** and supplies the read information to the hard disk drive **1540** and via the RAM **1520**. The input/output chip **1570** connects the flexible disk drive **1550** to each of the input/output apparatuses via, for example, a parallel port, a serial port, a keyboard port, a mouse port, or the like.

The programs provided to the hard disk **1540** via the RAM **1520** are stored on a recording medium such as the flexible disk **1590**, the CD-ROM **1595**, or an IC card and are provided by the user. The programs are read from the recording medium, installed on the hard disk drive **1540** in the image capturing system **10** via the RAM **1520**, and are performed by the CPU **1505**. The programs installed in the image capturing system **10** and executed by the image capturing system **10** affect the CPU **1505** to cause the image capturing system **10** to function as the image capturing section **110**, the image generating section **140**, the output section **180**, the control section **105**, the light irradiating section **150**, and the like described in relation to FIGS. **1** to **9**.

While the embodiments of the present invention have been described, the technical scope of the invention is not limited to the above described embodiments. It is apparent to persons skilled in the art that various alterations and improvements can be added to the above-described embodiments. It is also apparent from the scope of the claims that the embodiments added with such alterations or improvements can be included in the technical scope of the invention.

What is claimed is:

1. An image capturing system, comprising:

an image capturing section that includes a plurality of first light receiving elements that receive light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region, and a plurality of second light receiving elements that receive light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region; and

a control section that controls a spectrum of the light received by the plurality of first light receiving elements and the plurality of second light receiving elements, wherein

the control section, at a first timing, causes the plurality of first light receiving elements to receive light in a wavelength region including the first wavelength region from a subject and causes the plurality of second light receiving elements to receive light in a wavelength region including the second wavelength region from the subject and, at a second timing, causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in a wavelength region including the specified wavelength region from the subject.

2. The image capturing system according to claim 1, wherein

the control section, at the first timing, causes the plurality of first light receiving elements to receive light in the first wavelength region from the subject and causes the plurality of second light receiving elements to receive light in the second wavelength region from the subject and, at the second timing, causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in the specified wavelength region from the subject.

3. The image capturing system according to claim 2, wherein

the control section, at the second timing, causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in the specified wavelength region emitted by the subject.

4. The image capturing system according to claim 3, wherein

the control section, at the second timing, irradiates the subject with excitation light and causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in the specified wavelength region emitted by the subject, and

the excitation light is light in a wavelength region that excites a luminescent substance inside the subject such that the luminescent substance emits light in the specified wavelength region.

5. The image capturing system according to claim 4, wherein

the control section, at the first timing, causes the plurality of first light receiving elements to receive light in the first wavelength region reflected by the subject and causes the plurality of second light receiving elements to receive light in the second wavelength region reflected by the subject.

6. The image capturing system according to claim 5, wherein

the control section, at the first timing, irradiates the subject with light in a wavelength region including the first wavelength region and the second wavelength region, causes the plurality of first light receiving elements to receive light in the first wavelength region reflected by the subject, and causes the plurality of second light receiving elements to receive light in the second wavelength region reflected by the subject.

7. The image capturing system according to claim 6, wherein

the control section, at the second timing, irradiates the subject with the excitation light but not with light in a wavelength region including the first wavelength region and the second wavelength region, and causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in the specified wavelength region emitted by the subject.

8. The image capturing system according to claim 4, further comprising a plurality of light emitting elements that each emit light in a different spectrum, wherein

the control section controls irradiation of the subject with light at the first timing and the second timing by controlling emission intensity of each of the plurality of light emitting elements.

9. The image capturing system according to claim 7, further comprising:

a light emitting section that emits light in a wavelength region including the wavelength region of the excitation light, the first wavelength region, and the second wavelength region; and

an irradiation light cut filter section that allows light in the wavelength region of the excitation light to pass, but cuts light in the first wavelength region and light in the second wavelength region, wherein

the control section includes a light emission control section that irradiates the subject at the second timing with light emitted by the light emitting section through the irradiation light cut filter section.

10. The image capturing system according to claim 9, further comprising an excitation light cut filter section that allows light in the first wavelength region and light in the second wavelength region to pass, but cuts light in the wavelength region of the excitation light, wherein

the light emission control section irradiates the subject at the first timing with light emitted by the light emitting section through the excitation light cut filter section.

11. The image capturing system according to claim 1, further comprising:

a signal adding section that adds together (i) a pixel signal from at least one of the plurality of first light receiving elements and (ii) a pixel signal from at least one of the plurality of second light receiving elements; and

a specified wavelength region image generating section that generates a specified wavelength region image at the second timing based on the added pixel signals.

12. The image capturing system according to claim 1, further comprising:

a movement identifying section that identifies movement of an object between images obtained at a plurality of first timings, based on a plurality of images resulting from light received by the plurality of first light receiving elements or the plurality of second light receiving elements at the plurality of first timings; and

a subject image generating section that generates a subject image at the second timing resulting from light in a wavelength region including the first wavelength region and light in a wavelength region including the second wavelength region, based on light in the first wavelength region received by the plurality of first light receiving elements at the plurality of first timings, light in the second wavelength region received by the plurality of second light receiving elements at the plurality of first timings, and the movement of the object.

13. The image capturing system according to claim **1**, wherein

the image capturing section further includes a plurality of third light receiving elements that receive light in the specified wavelength region and light in a third wavelength region, which is different from the specified wavelength region, and

the control section, at the first timing, causes the plurality of first light receiving elements, the plurality of second light receiving elements, and the plurality of third light receiving elements to respectively receive light in a wavelength region including the first wavelength region from the subject, light in a wavelength region including the second wavelength region from the subject, and light in a wavelength region including the third wavelength region from the subject and, at the second timing, causes the plurality of first light receiving elements, the plurality of second light receiving elements, and the plurality of third light receiving elements to receive light in a wavelength region including the specified wavelength region from the object.

14. An image capturing method, comprising:

capturing an image with a plurality of first light receiving elements that receive light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region, and with a plurality of second light receiving elements that receive light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region; and

controlling a spectrum of the light received by the plurality of first light receiving elements and the plurality of second light receiving elements, wherein

the controlling involves, at a first timing, causing the plurality of first light receiving elements to receive light in a wavelength region including the first wavelength region from a subject and causing the plurality of second light receiving elements to receive light in a wavelength region including the second wavelength region from the subject and, at a second timing, causing the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in a wavelength region including the specified wavelength region from the subject.

15. A computer readable medium storing thereon a program for use by an image capturing system, the program causing the image capturing system to function as:

an image capturing section that captures an image using a plurality of first light receiving elements that receive light in a specified wavelength region and light in a first wavelength region, which is different from the specified wavelength region, and a plurality of second light receiving elements that receive light in the specified wavelength region and light in a second wavelength region, which is different from the specified wavelength region; and

a control section that controls a spectrum of the light received by the plurality of first light receiving elements and the plurality of second light receiving elements and, at a first timing, causes the plurality of first light receiving elements to receive light in a wavelength region including the first wavelength region from a subject and causes the plurality of second light receiving elements to receive light in a wavelength region including the second wavelength region from the subject and, at a second timing, causes the plurality of first light receiving elements and the plurality of second light receiving elements to receive light in a wavelength region including the specified wavelength region from the subject.

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